Appendix C

➢ INDUCED GROWTH MEMO

Transportation
Land Development
Environmental
Services

Vanasse Hangen Brustlin, Inc.

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Memorandum

To: Jeff Brillhart

Date: October 17, 2000

Project No.: 50885

From: Marty Kennedy

Re: I-93 Induced Travel

Introduction

Induced travel is a relatively new term that generally refers to any increase in travel that results solely from increasing the capacity of the transportation system. The concept of induced travel, which is not widely understood, is being used by some to suggest that adding roadway capacity does little to reduce traffic congestion. This conclusion may be based on a misunderstanding as to what induced travel is and what it is not. This is not to say that induced travel is not real. I believe it is. However, with the limited and contradictory research currently available, it is not easy to quantify the effect of induced travel. The purpose of this memorandum is to bring some clarity to the issue and to recommend a strategy to address the issue of induced travel as it specifically pertains to the I-93 corridor.

As requested, in an effort to address the issue of induced travel and specifically to respond to comments raised by the EPA, Vanasse Hangen Brustlin, Inc. (VHB) has reviewed some of the recent literature on the subject. Included in the review were the following papers:

(1) Induced Travel: A Review of Recent Literature and the Implications for Transportation and Environmental Policy: Noland & Lem, July 20, 2000.

(2) Induced Highway Travel: Transportation Policy Implications for Congested Metropolitan Areas: DeCorla-Souza, Transportation Quarterly, Vol. 54 No.2, Spring 2000 (13-30), 2000 Eno Transportation Foundation, Inc. Washington, D.C.

(3) Land Use Impacts of Transportation a Guidebook: NCHRP Report 423A Transportation Research Board, Washington, D.C. 1999

(4) Accounting for Induced Travel in Evaluation of Urban Highway Expansion: DeCorla-Souza & Cohen, FHWA, Surface Transportation Efficiency Analysis Model (STEAM) White Paper – Session No. 9.

In addition to reviewing the above referenced papers, we have reviewed the FHWA's *Spreadsheet Model for Induced Travel* (SMITE).

What is Induced Travel?

There are varying interpretations as to what induced travel is. As stated previously induced travel is perceived as an increase in travel that results solely from an increase in the capacity of the transportation system. That is, induced travel is not an increase in travel due to demographic changes in population, income levels, or markets. Nor is it an increase in travel due to technological improvements in vehicle efficiency or comfort, or in technological advances that allow for the enjoyment of resources that were previously available only in more urbanized areas. In an effort to further qualify and define induced travel, one must consider the following issues and resultant types of induced travel as well as the source of induced travel.

- Travel Mode – Is the travel referring to "person trips" or "vehicle trips"?

- Length of trip – Does induced travel refer to new trips or does it also refer to the lengthening of existing trips?

- Time of trip – Does induced travel include the motorist that shifts his or her trip into the peak hour without resulting in new daily trips?

- Region or corridor specific – Are diverted trips that shift from one corridor to another induced if on a regional basis there is no increase in trips?

- Long term effects- Is the induced travel a temporary situation or permanent?

As described by DeCorla-Souza (2), the factors that are relevant to induced travel are:

1. "Vehicle, not person trips;
2. length of vehicle trips (i.e. vehicle miles, in addition to number of vehicle trips);
3. vehicle miles daily, not necessarily its distribution between peak and off-peak periods;
4. region-wide daily vehicle miles, or vehicle miles in a specific corridor or on a specific facility; and
5. long-term effects."

Based on these relevant factors, DeCorla-Souza defines induced travel as "any increase in daily vehicle miles of travel (Daily VMT) in the long-term at the regional level resulting from expansion of the highway system." This global definition of induced travel includes more vehicle trips, longer trips, and diverted trips. Beyond the initial improvement in transportation which improves mobility and access, the sources of induced travel include increases in residential development; increases in commercial and industrial development; increases in the number of trips between residential and commercial/industrial developments; increases in trip distances; increases in automobile travel at the expense of transit travel; and increases in travel on one corridor at the expense of another corridor.

Quantifying Induced Travel

To quantify the level of induced travel it is necessary to isolate the induced travel portion of the travel increase from the increase in travel that occurs due to other factors such as population growth, increases in income, technological advances, cultural norms, etc. To date efforts to quantify that portion of the travel increases that represents induced travel have involved trying to determine the elasticity of travel demand with respect to any increase in capacity. The idea is that an increase in capacity will reduce congestion and consequently reduce travel time that will in turn encourage (or induce) more travel. The elasticity is defined as the percent change in travel in response to a percent change in travel time. Some researchers have estimated elasticities as high as 1.0, which would suggest for every percent increase in capacity there would be a corresponding increase in induced travel. Clearly, these studies overstate the influence of induced travel. Merely showing a correlation between an increase in capacity and an increase in VMT does not demonstrate causation.

Intuitively, the concept of induced travel makes sense. It is based on the economic principle of supply and demand. If you increase the capacity of the highway (the supply) you would reduce the travel time or the cost of travel (*time is money*). It seems reasonable that any reduction in the cost of travel would result in an increase in the demand for travel. The magnitude of the change is represented by the elasticity of travel demand with respect to a change in travel time. However, determining what elasticity is appropriate for any specific instance is not easily done given the other factors at work to increase travel such as demographic changes, technological advances, cultural biases, etc.

Current traffic modeling techniques estimate growth projections based on demand, independent of the capacity constraints of the highway system. Estimating future demand in this manner does not necessarily result in an underestimate or an overestimate. What it does result in is future No Build and Build traffic networks with similar traffic volumes. Current traffic models do generally account for traffic diverting from one facility to another so there are some differences, but the differences do not account for all of the influence of induced travel. This is not to say that current traffic models always underestimate the influence of induced travel. In fact, if the demand projections are accurate and are estimated independent of the roadway system's capacity constraints, it would be more likely that the No Build condition is overestimated than that the Build condition is underestimated.

How should we proceed?

The bottom line is that the concept of induced travel, as it relates to the I-93 corridor, is an important issue and needs to be recognized so that the decision makers can fully appreciate the potential ramifications of upgrading the corridor. However, it is also important to recognize that research on this subject is still in its infancy stage and that there are no accepted standards for quantifying the impacts of induced travel. For our purposes, I would recommend the following:

1. We should be upfront in recognizing and openly discussing the issue of induced travel. We should not be seen as being defensive or ignoring the issue.
2. We should be clear in defining what induced travel is and what it is not. We should also stress that research in this area is limited and there are currently no accepted standards for quantifying induced travel.
3. We should address the issue of induced travel in the DEIS as a secondary impact. We should not be making any changes to our projected traffic volume networks at this time.
4. The Department should encourage local communities and the regional planning commissions to address the issue from a land use policy perspective.
5. We should also keep in mind that given the conservative (i.e. low) future traffic volume projections that we are using and, the fact that the Department may ultimately accept less than desirable LOS conditions, the Department is already doing what it can to not over design the corridor. Additionally, by providing park and ride lots, enhancing bus service and making provisions for future rail service, the Department is again doing what it can to reduce the potentially adverse impact of vehicular traffic.

Appendix D

- **SMITE MEMO**

[redacted]
Vanasse Hangen Brustlin, Inc.

Transportation
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Memorandum

To:	Jeff Brillhart - NHDOT	Date:	January 10, 2001
		Project No.:	50885
From:	Martin F. Kennedy, P.E.	Re:	Summary of Induced Travel Estimates Using SMITE Spreadsheet

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Introduction

As a supplement to our October 17, 2000 memorandum on the subject of induced travel, this memorandum summarizes the results of some trial runs of the Federal Highway Administration's (FHWA) "Spreadsheet Model for Induced Travel Estimation" (SMITE) that have been conducted by VHB. Patrick DeCorla-Souza and Harry Cohen in their paper titled Accounting for Induced Travel in Evaluation of Urban Highway Expansion suggest that "the SMITE spreadsheet can be used at a sketch planning level of an analysis to estimate the potential effects of induced travel". However, it is important to recognize that the SMITE spreadsheet is no more or less than a calculator and a tool that provides an estimate of the level of induced travel based on various input variables.

VHB contacted Mr. DeCorla-Souza, one of the principal authors of the Smite spreadsheet, to discuss the application of the spreadsheet and the general concept of induced travel. Mr. DeCorla-Souza stressed that the spreadsheet is a sketch-planning tool and he recognizes the spreadsheet's limitations and the need for additional research on the subject.

Two of the principal input variables are 1) the elasticity of travel demand and 2) the ratio of freeway traffic to arterial traffic. Because much of the current debate and ongoing research is focused on quantifying the level of elasticity, it is important to recognize that any result from the spreadsheet is only as good as the input elasticity. Similarly, the ratio of freeway traffic to arterial traffic is somewhat subjective as the extent of the influence area can vary widely.

The bottom line is that this memorandum is not an endorsement of the method or the results of the SMITE spreadsheet analyses. We believe that induced travel is a real phenomenon and that there is a relationship between available roadway capacity and land development. However, research in the area of quantifying the effect of induced travel is still in its infancy and more study is needed. Having said that, the following paragraphs present the results of the SMITE spreadsheet analyses.

Trials were conducted using various combinations of the following input data: 1) Ratio of Base Freeway to Arterial Traffic 2) Percent Increase in Freeway Capacity and, 3) Demand Elasticity. Tables 1 – 3 present percentage changes in freeway, arterial and corridor-wide VMT for the various runs.

Results

Table 1 presents the results of a spreadsheet trial assuming three different combinations of initial freeway and arterial study area traffic. Alternatives 1, 2, and 3 use 30 percent freeway/70 percent arterial, 50 percent freeway/50 percent arterial, and 70 percent freeway/30 percent arterial respectively. An elasticity of –0.50 and an increase in freeway capacity of 50 percent are held constant for each of the three alternatives.

As shown in the table each of the alternatives results in an increase in freeway VMT ranging from approximately 35 percent (Alternative 1) to 17 percent (Alternative 3). Reductions in arterial VMT ranged from approximately 19 percent (Alternative 3) to 10 percent (Alternative 1). The three scenarios resulted in an increase in corridor VMT of approximately 3 percent for Alternative 1, 5 percent for Alternative 2 and 6 percent for Alternative 3.

Table 1
Change in Daily VMT Resulting from Modifications to the Ratio of Initial Base Freeway/Arterial Traffic

	Alternative 1*	Alternative 2**	Alternative 3+
Percent Change in Freeway VMT	34.8	25.7	17.4
Percent Change in Arterial VMT	-10.0	-15.0	-19.4
Percent Change in Corridor VMT	3.4	5.1	6.0

* Alternative 1 represents an Initial Travel Demand of: freeway – 30 percent/arterial – 70 percent.
** Alternative 2 represents an Initial Travel Demand of: freeway – 50 percent/arterial – 50 percent.
\+ Alternative 3 represents an Initial Travel Demand of: freeway – 70 percent/arterial – 30 percent.

Table 2 presents the result of a spreadsheet trial for various combinations of freeway capacity increases. Alternatives 1, 2 and 3 evaluate increases in freeway capacity of 25 percent, 50 percent, and 75 percent respectively. An elasticity of –0.5 and a freeway traffic to arterial traffic ratio of 40 percent/60 percent is held constant for each of the three alternatives.

The results of the analyses show increases in overall corridor VMT ranging from 3 to 6 percent. Increases in VMT along the freeway range from 17 percent to 41 percent while the arterials show reductions in VMT ranging from 7 to 17 percent.

Table 2
Change in Daily VMT Resulting from Increases in Highway Capacity

	Alternative 1*	Alternative 2**	Alternative 3+
Percent Change in Freeway VMT	16.7	30.1	40.8
Percent Change in Arterial VMT	-6.9	-12.5	-17.3
Percent Change in Corridor VMT	2.5	4.3	5.6

* Alternative 1 represents a 25 percent increase in freeway capacity.
** Alternative 2 represents a 50 percent increase in freeway capacity.
\+ Alternative 3 represents a 75 percent increase in freeway capacity.

Finally, Table 3 summarizes the results of an evaluation of varying levels of demand elasticity. The scenarios consist of demand elasticities of –0.25, -0.50, and –1.00. An increase in freeway capacity of 50 percent, and a freeway traffic to arterial traffic ratio of 40 percent/60 percent is held constant for each of the three alternatives.

The results of the analyses reveal increases in overall corridor VMT ranging from 2 to 8 percent. Increases in VMT along the freeway range from 28 percent to 35 percent while the arterials show reductions in VMT ranging from 9 to 15 percent.

Table 3
Change in Daily VMT Resulting from Changes in Demand Elasticity

	Alternative 1*	Alternative 2**	Alternative 3+
Percent Change in Freeway VMT	27.6	30.1	34.8
Percent Change in Arterial VMT	-14.6	-12.5	-8.7
Percent Change in Corridor VMT	2.2	4.3	8.0

* Alternative 1 represents a demand elasticity of –0.25.
** Alternative 2 represents a demand elasticity of –0.50.
\+ Alternative 3 represents a demand elasticity of –1.00.

Summary

The purpose of running the SMITE spreadsheet for the various input variables was to begin to establish a range of the potential effect of induced travel. As the results indicate, the increase in VMT for the overall study corridor (freeway and arterials) is relatively low – ranging from 2 to 8 percent. However, the level of increase in VMT on the freeway can be substantial and varies widely – ranging from 17 to 41 percent. Once again, caution should be used in drawing definitive conclusions from this analysis. This analysis is best used for the purpose of further discussion.

PART 1: 'APPLICATION TO ESTIMATE INDUCED VMT IN A FREEWAY CORRIDOR

		Alternative Forecasts for "Base" Travel		
		Alt.1	**Alt.2**	**Alt.3**
	Assumed Elasticity of Demand w.r.t. Travel Time	**-0.50**	**-0.50**	**-0.50**
INITIAL CONDITIONS				
Travel Demand				
A1	Initial daily VMT (all fac. classes)	**3,420,000**	**3,420,000**	**3,420,000**
A2	Percent on freeways	**30.00%**	**50.00%**	**70.00%**
A3	Percent on arterials	**70.00%**	**50.00%**	**30.00%**
A4	Initial freeway VMT	**1,026,000**	**1,710,000**	**2,394,000**
A5	Initial arterial VMT	2,394,000	1,710,000	1,026,000
Conditions Before Improvement (Freeway)				
B1	Initial AADT/C ratio for freeways	**9.5**	**9.5**	**9.5**
B2	Initial freeway hourly capacity (in VMT)	108,000	180,000	252,000
B3	Initial freeway daily delay (hrs/1000 VMT)	3.03	3.03	3.03
B4	Initial freeway speed	50.76	50.76	50.76
B5	Initial freeway VHT	20,213	33,688	47,164
Conditions Before Improvement (Arterials)				
B6	Initial AADT/C ratio for arterials	**6.65**	**6.65**	**6.65**
B7	Initial arterial hourly capacity (in VMT)	360,000	257,143	154,286
B8	Initial arterial daily delay (hrs/1000 VMT)	28.12	28.12	28.12
B9	Initial arterial speed	18.82	18.82	18.82
B10	Initial arterial VHT	127,177	90,840	54,504
Conditions Before Improvement (Corridor)				
B11	Total corridor VHT	147,390	124,529	101,668
B12	Avg corridor speed (mph)	23.20	27.46	33.64
B13	Avg corridor travel time per mile	0.04	0.04	0.03
FREEWAY ANALYSIS				
Initial Conditions After Improvement				
C1	Percent increase in freeway hourly capacity	**0.5**	**0.5**	**0.5**
C2	Freeway hourly capacity after impr. (VMT)	162,000	270,000	378,000
C3	Initial AADT/C ratio for freeways	6	6	6
C4	Initial freeway hourly capacity (in VMT)	162,000	270,000	378,000
C5	Initial freeway daily delay (hrs/1000 VMT)	0.71	0.71	0.71
C6	Initial freeway speed	57.55	57.55	57.55
C7	Initial freeway VHT	17,829	29,715	41,601
C8	VMT diverted from arterials	312,261	342,000	266,000
C9	Initial freeway VMT after improvement	1,338,261	2,052,000	2,660,000
C10	Initial freeway ADT/C with diverted traffic	8.26	7.60	7.04
C12	Freeway daily delay with diver.(hrs/1000 VMT)	1.38	0.97	0.79
C13	Freeway avg. speed after impr., with diversion	55.41	56.71	57.29
C14	Freeway VHT with diver., for previous travelers	18,516	30,153	41,790
C15	Added VMT from diversion (in thousands)	312	342	266
C16	Previous VMT(in thousands)	1,026	1,710	2,394
C17	Incr. in delay (hrs) to previous VMT due to diver.	687	438	189
C18	Added delay (hrs) to prev. VMT/1000 added VMT	2.20	1.28	0.71

SUMMARIES

CHANGE IN DAILY VMT DUE TO EXPANSION OF FREEWAY CAPACITY

	Alternative Forecasts for "Base" Travel		
	Alt.1	**Alt.2**	**Alt.3**
Freeway:			
Initial VMT	1,026,000	1,710,000	2,394,000
Diverted VMT	312,261	342,000	266,000
Induced VMT	44,324	96,735	150,851
Total VMT after improvement	1,382,585	2,148,735	2,810,851
Percent change in VMT	34.75%	25.66%	17.41%
Arterials:			
Initial VMT	2,394,000	1,710,000	1,026,000
Diverted VMT	(312,261)	(342,000)	(266,000)
Induced VMT	74,055	85,629	67,197
Total VMT after improvement	2,155,794	1,453,629	827,197
Percent change in VMT	-9.95%	-14.99%	-19.38%
Corridorwide:			
Initial VMT	3,420,000	3,420,000	3,420,000
Diverted VMT	0	0	0
Induced VMT	118,379	182,364	218,048
Total VMT after improvement	3,538,379	3,602,364	3,638,048
Percent change in VMT	3.35%	5.06%	5.99%

DAILY MOBILITY BENEFITS TO HIGHWAY USERS

	Alternative Forecasts for "Base" Travel		
	Alt.1	**Alt.2**	**Alt.3**
Freeway:			
Initial speed before improvement (mph)	50.76	50.76	50.76
Final speed after improvement (mph)	54.64	56.10	56.92
Arterials:			
Initial speed before improvement (mph)	18.82	19.03	19.03
Final speed after improvement (mph)	19.22	19.30	19.33
Value of time savings:			
Freeway, previous users	$17,227	$38,495	$61,275
Freeway diverted users	$2,622	$3,849	$3,404
Freeway, induced users	$372	$1,089	$1,931
Arterial, previous users	$27,162	$12,086	$7,454
Arterial, induced users	$483	$378	$330
GRAND TOTAL	$47,866	$55,897	$74,393

PART 1: 'APPLICATION TO ESTIMATE INDUCED VMT IN A FREEWAY CORRIDOR

		Alternative Forecasts for "Base" Travel		
		Alt.1	**Alt.2**	**Alt.3**
	Assumed Elasticity of Demand w.r.t. Travel Time	**-0.50**	**-0.50**	**-0.50**
INITIAL CONDITIONS				
Travel Demand				
A1	Initial daily VMT (all fac. classes)	**3,420,000**	**3,420,000**	**3,420,000**
A2	Percent on freeways	**40.00%**	**40.00%**	**40.00%**
A3	Percent on arterials	**60.00%**	**60.00%**	**60.00%**
A4	Initial freeway VMT	**1,368,000**	**1,368,000**	**1,368,000**
A5	Initial arterial VMT	2,052,000	2,052,000	2,052,000
Conditions Before Improvement (Freeway)				
B1	Initial AADT/C ratio for freeways	**9.5**	**9.5**	**9.5**
B2	Initial freeway hourly capacity (in VMT)	144,000	144,000	144,000
B3	Initial freeway daily delay (hrs/1000 VMT)	3.03	3.03	3.03
B4	Initial freeway speed	50.76	50.76	50.76
B5	Initial freeway VHT	26,951	26,951	26,951
Conditions Before Improvement (Arterials)				
B6	Initial AADT/C ratio for arterials	**6.65**	**6.65**	**6.65**
B7	Initial arterial hourly capacity (in VMT)	308,571	308,571	308,571
B8	Initial arterial daily delay (hrs/1000 VMT)	28.12	28.12	28.12
B9	Initial arterial speed	18.82	18.82	18.82
B10	Initial arterial VHT	109,008	109,008	109,008
Conditions Before Improvement (Corridor)				
B11	Total corridor VHT	135,959	135,959	135,959
B12	Avg corridor speed (mph)	25.15	25.15	25.15
B13	Avg corridor travel time per mile	0.04	0.04	0.04
FREEWAY ANALYSIS				
Initial Conditions After Improvement				
C1	Percent increase in freeway hourly capacity	**0.25**	**0.5**	**0.75**
C2	Freeway hourly capacity after impr. (VMT)	180,000	216,000	252,000
C3	Initial AADT/C ratio for freeways	8	6	5
C4	Initial freeway hourly capacity (in VMT)	180,000	216,000	252,000
C5	Initial freeway daily delay (hrs/1000 VMT)	0.97	0.71	0.71
C6	Initial freeway speed	56.71	57.55	57.56
C7	Initial freeway VHT	24,122	23,772	23,767
C8	VMT diverted from arterials	186,545	342,000	473,538
C9	Initial freeway VMT after improvement	1,554,545	1,710,000	1,841,538
C10	Initial freeway ADT/C with diverted traffic	8.64	7.92	7.31
C12	Freeway daily delay with diver.(hrs/1000 VMT)	1.74	1.13	0.86
C13	Freeway avg. speed after impr., with diversion	54.32	56.18	57.06
C14	Freeway VHT with diver., for previous travelers	25,186	24,349	23,974
C15	Added VMT from diversion (in thousands)	187	342	474
C16	Previous VMT(in thousands)	1,368	1,368	1,368
C17	Incr. in delay (hrs) to previous VMT due to diver.	1,064	577	207
C18	Added delay (hrs) to prev. VMT/1000 added VMT	5.70	1.69	0.44

SUMMARIES

CHANGE IN DAILY VMT DUE TO EXPANSION OF FREEWAY CAPACITY

	Alternative Forecasts for "Base" Travel		
	Alt.1	**Alt.2**	**Alt.3**
Freeway:			
Initial VMT	1,368,000	1,368,000	1,368,000
Diverted VMT	186,545	342,000	473,538
Induced VMT	41,491	69,784	83,874
Total VMT after improvement	1,596,037	1,779,784	1,925,413
Percent change in VMT	16.67%	30.10%	40.75%
Arterials:			
Initial VMT	2,052,000	2,052,000	2,052,000
Diverted VMT	(186,545)	(342,000)	(473,538)
Induced VMT	44,285	85,247	119,095
Total VMT after improvement	1,909,739	1,795,247	1,697,557
Percent change in VMT	-6.93%	-12.51%	-17.27%
Corridorwide:			
Initial VMT	3,420,000	3,420,000	3,420,000
Diverted VMT	0	0	0
Induced VMT	85,776	155,031	202,970
Total VMT after improvement	3,505,776	3,575,031	3,622,970
Percent change in VMT	2.45%	4.34%	5.60%

DAILY MOBILITY BENEFITS TO HIGHWAY USERS

	Alternative Forecasts for "Base" Travel		
	Alt.1	**Alt.2**	**Alt.3**
Freeway:			
Initial speed before improvement (mph)	50.76	50.76	50.76
Final speed after improvement (mph)	53.50	55.47	56.65
Arterials:			
Initial speed before improvement (mph)	18.82	19.03	19.03
Final speed after improvement (mph)	19.10	19.27	19.32
Value of time savings:			
Freeway, previous users	$16,596	$27,443	$33,641
Freeway diverted users	$1,132	$3,430	$5,822
Freeway, induced users	$252	$700	$1,031
Arterial, previous users	$17,397	$13,608	$14,890
Arterial, induced users	$206	$339	$562
GRAND TOTAL	$35,583	$45,520	$55,946

PART 1: 'APPLICATION TO ESTIMATE INDUCED VMT IN A FREEWAY CORRIDOR

		Alternative Forecasts for "Base" Travel		
		Alt.1	**Alt.2**	**Alt.3**
	Assumed Elasticity of Demand w.r.t. Travel Time	**-0.25**	**-0.50**	**-1.00**
INITIAL CONDITIONS				
Travel Demand				
A1	Initial daily VMT (all fac. classes)	**3,420,000**	**3,420,000**	**3,420,000**
A2	Percent on freeways	**40.00%**	**40.00%**	**40.00%**
A3	Percent on arterials	**60.00%**	**60.00%**	**60.00%**
A4	Initial freeway VMT	**1,368,000**	**1,368,000**	**1,368,000**
A5	Initial arterial VMT	2,052,000	2,052,000	2,052,000
Conditions Before Improvement (Freeway)				
B1	Initial AADT/C ratio for freeways	**9.5**	**9.5**	**9.5**
B2	Initial freeway hourly capacity (in VMT)	144,000	144,000	144,000
B3	Initial freeway daily delay (hrs/1000 VMT)	3.03	3.03	3.03
B4	Initial freeway speed	50.76	50.76	50.76
B5	Initial freeway VHT	26,951	26,951	26,951
Conditions Before Improvement (Arterials)				
B6	Initial AADT/C ratio for arterials	**6.65**	**6.65**	**6.65**
B7	Initial arterial hourly capacity (in VMT)	308,571	308,571	308,571
B8	Initial arterial daily delay (hrs/1000 VMT)	28.12	28.12	28.12
B9	Initial arterial speed	18.82	18.82	18.82
B10	Initial arterial VHT	109,008	109,008	109,008
Conditions Before Improvement (Corridor)				
B11	Total corridor VHT	135,959	135,959	135,959
B12	Avg corridor speed (mph)	25.15	25.15	25.15
B13	Avg corridor travel time per mile	0.04	0.04	0.04
FREEWAY ANALYSIS				
Initial Conditions After Improvement				
C1	Percent increase in freeway hourly capacity	**0.5**	**0.5**	**0.5**
C2	Freeway hourly capacity after impr. (VMT)	216,000	216,000	216,000
C3	Initial AADT/C ratio for freeways	6	6	6
C4	Initial freeway hourly capacity (in VMT)	216,000	216,000	216,000
C5	Initial freeway daily delay (hrs/1000 VMT)	0.71	0.71	0.71
C6	Initial freeway speed	57.55	57.55	57.55
C7	Initial freeway VHT	23,772	23,772	23,772
C8	VMT diverted from arterials	342,000	342,000	342,000
C9	Initial freeway VMT after improvement	1,710,000	1,710,000	1,710,000
C10	Initial freeway ADT/C with diverted traffic	7.92	7.92	7.92
C12	Freeway daily delay with diver.(hrs/1000 VMT)	1.13	1.13	1.13
C13	Freeway avg. speed after impr., with diversion	56.18	56.18	56.18
C14	Freeway VHT with diver., for previous travelers	24,349	24,349	24,349
C15	Added VMT from diversion (in thousands)	342	342	342
C16	Previous VMT(in thousands)	1,368	1,368	1,368
C17	Incr. in delay (hrs) to previous VMT due to diver.	577	577	577
C18	Added delay (hrs) to prev. VMT/1000 added VMT	1.69	1.69	1.69

SUMMARIES

CHANGE IN DAILY VMT DUE TO EXPANSION OF FREEWAY CAPACITY

	Alternative Forecasts for "Base" Travel		
	Alt.1	Alt.2	Alt.3
Freeway:			
Initial VMT	1,368,000	1,368,000	1,368,000
Diverted VMT	342,000	342,000	342,000
Induced VMT	35,699	69,784	133,529
Total VMT after improvement	1,745,699	1,779,784	1,843,529
Percent change in VMT	27.61%	30.10%	34.76%
Arterials:			
Initial VMT	2,052,000	2,052,000	2,052,000
Diverted VMT	(342,000)	(342,000)	(342,000)
Induced VMT	42,150	85,247	164,563
Total VMT after improvement	1,752,150	1,795,247	1,874,563
Percent change in VMT	-14.61%	-12.51%	-8.65%
Corridorwide:			
Initial VMT	3,420,000	3,420,000	3,420,000
Diverted VMT	0	0	0
Induced VMT	77,849	155,031	298,092
Total VMT after improvement	3,497,849	3,575,031	3,718,092
Percent change in VMT	2.23%	4.34%	8.02%

DAILY MOBILITY BENEFITS TO HIGHWAY USERS

	Alternative Forecasts for "Base" Travel		
	Alt.1	Alt.2	Alt.3
Freeway:			
Initial speed before improvement (mph)	50.76	50.76	50.76
Final speed after improvement (mph)	55.84	55.47	54.64
Arterials:			
Initial speed before improvement (mph)	18.82	19.03	19.03
Final speed after improvement (mph)	19.38	19.27	19.22
Value of time savings:			
Freeway, previous users	$29,426	$27,443	$22,963
Freeway diverted users	$3,678	$3,430	$2,870
Freeway, induced users	$384	$700	$1,121
Arterial, previous users	$31,514	$13,608	$10,473
Arterial, induced users	$388	$339	$504
GRAND TOTAL	$65,390	$45,520	$37,932

Appendix E

➤ SHOULDER LANE USE MEMO

Transportation
Land Development
Environmental
Services

Vanasse Hangen Brustlin, Inc.

Kilton Road
Six Bedford Farms, Suite 607
Bedford, New Hampshire 03110-6532
603 644-0888
FAX 603 644-2385

Memorandum

To: Jeff Brillhart

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Date: January 15, 2001

Project No.: 50885

From: Vanasse Hangen Brustlin, Inc.

Re: Consideration of I-93 Shoulder Lane Use During Peak Hours

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Project Description

Consideration of peak period use of the shoulder along Interstate 93 (I-93) in New Hampshire as a travel lane arose as a possible short-term option during discussions regarding alternatives to address existing corridor congestion. Based on a review of the existing traffic operations for I-93, the area that was of particular interest to evaluate the use of a shoulder lane treatment to reduce congestion during the evening peak period was the northbound section of I-93 between Exit 1 (Rockingham Boulevard) in Salem and Exit 3 (NH 111) in Windham, a distance of 3.9 miles.

This memorandum presents an analysis of the use of the shoulder as a means of providing added capacity to the corridor. A historical review of the use of a shoulder lane as a means of increasing capacity and a review of the safety issues associated with its use is discussed. More importantly, a review of the existing geometric conditions that exist along I-93 from the Massachusetts/New Hampshire State Line to Exit 3 (NH 111) is provided and compared to current design standards.

Shoulder Lane Study Area

The study area, which extends along I-93 from the Massachusetts/New Hampshire State Line to Exit 3 (NH 111) is part of the interstate highway system and travels through the towns of Salem and Windham, New Hampshire. There are three interchanges within the study area limits, which provide access to regional and local roadway corridors:

- Exit 1 – Rockingham Boulevard
- Exit 2 – Pelham Road
- Exit 3 – NH 111

Historical Use of Shoulder Lanes

The use of shoulders, or breakdown lanes, as travel lanes has been in existence since the late 1960s in the United States. More than 24 states have implemented projects involving the use of shoulders as a means of providing additional travel lanes since that time. A number of states use the shoulder lanes in a more limited and specific capacity; for example, lanes have been restricted to high occupancy vehicles (HOV), used during times of construction, and used to provide additional acceleration and deceleration lanes. Typically, opening shoulder lanes for travel during peak hours is primarily viewed as a temporary solution to peak period congestion until permanent solutions are constructed.

In many cases, the possibility of expanding the use of the shoulder lane, without substantial capital investment, is limited by the presence of geometric and/or physical barriers along the roadway such as bridge abutments or narrow existing shoulders. While the traffic analysis may indicate that the use of the shoulder lane will provide relief during the peak period of congestion, the cost of providing for safe travel may be considered too great a capital investment to justify a temporary solution.

Safety

The issue of safety is a source of debate when the use of a shoulder for general traffic is considered. One argument is that accident rates would increase because of the more complicated merging movements and the limiting factors of closing the shoulders. These safety issues have been studied in both the National Cooperative Highway Research Project's (NCHRP) *Use of Shoulders and Narrow Lanes to Increase Freeway Capacity*[1] and by the State of Massachusetts Central Transportation Planning Staff's (CTPS) *Safety Implications of Using Highway Shoulders as Travel Lanes*[2]. These papers concentrated on automobile accidents on the mainline, shoulders, and acceleration/deceleration lanes.

The NCHRP study on the use of shoulders reviewed accident rates of a wide range of roadways across the United States where a shoulder was used as a temporary travel lane, or as a permanent travel lane. The study compared rates before and after the lanes were opened to general traffic use. The finding presented in the report indicated that where shoulders were used and a full 12-foot lane was not provided, accident rates increased. This increase in accident trends was particularly noticeable during the first two years of inception. However, as drivers became more familiar with the use of the shoulder lanes, this rate tended to decline to a point where accidents were consistently 10-15 percent higher than the condition prior to the use of the shoulder as a travel way. In locations where shoulders were used and a full 12-foot lane was provided, the study did not reveal statistical correlation to increases in accident trends.

In the memorandum by CTPS, the accident rates (per 100 million vehicle miles of travel) on an unaltered (shoulder lane not in use) section of Route 128 in the Town of Weston, Massachusetts and an altered section of Route 128 in the Town of Needham, Massachusetts were compared. The memo concluded, "*there is a possible difference in rates for total accidents and for accidents involving property damage. In these instances, the total accident rate is higher for the altered segment than it is for the unaltered segment but, the rate for accidents involving property damage only is higher for the unaltered segment than it is for the altered segment*." Essentially CTPS concluded that it is hard to determine whether allowing travel in the shoulder lane increases the traffic accident rate or not. In fact, the difference found in accident rates may have nothing to do with the shoulder lane utilization but rather caused by the differences in roadway characteristics. For example, the two segments compared have different spacing of interchanges, on/off-ramp volumes, and number of weaving areas. For the best

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[1] Report 369 - Use of Shoulders and Narrow Lanes to Increase Freeway Capacity; National Cooperative Highway Research Project, Transportation Research Board; Washington DC 1995

[2] Safety Implications of Using Highway Shoulders as Travel Lanes; Alicia Powell Wilson, Central Transportation Planning Staff; Boston, Massachusetts; April 1997.

comparison, the two (altered and unaltered) road segments should have comparable traffic volumes and vehicle mix, similar speeds, and similar geometric conditions, isolating the use of the shoulder lane as the only significant difference.

To support the conclusion presented by CTPS and NCHRP, the Massachusetts Highway Department (MassHighway) compared traffic accident information gathered between 1986 and 1990 along I-93/I-95 and Route 3 where the breakdown lane was in use to determine the relative accident trends as drivers became more comfortable with shoulder lane use. The result of this comparison shows that there has been a decrease in the rate of accidents over this time period. Accident rates (number of accidents per million vehicle miles of travel) along Route 3 have dropped approximately 20 percent between 1986 and 1990. The rates along I-93/I-95 indicate a drop of approximately 23 percent during the same time period.

In either case, both the NCHRP and CTPS technical reports indicate that there is a general statistical increase in accident rates following the opening of the shoulder lane. As drivers become more familiar with the use of the breakdown lane, these accident rates decrease over time, as was further confirmed by the MassHighway study.

Existing Conditions

This section includes a review of existing geometric conditions for I-93 NB within the study area. It has been identified in the I-93 *Scoping Report*, published in May 2000, that the I-93 NB barrel between Exit 1 and Exit 3 currently is operating at a capacity condition. While existing operating conditions justify the potential use of the shoulder as a means of providing additional capacity, several other factors must be considered prior to authorizing the use of the lane. Specifically, the use of the lane must be feasible to implement. This section of the memorandum summarizes current design standards and the I-93 corridor's ability to accommodate shoulder lane use.

Roadway Description

Within the study area, I-93 NB travels through Salem and Windham, New Hampshire. Upon entering New Hampshire, the I-93 NB barrel consists of four lanes south of Exit1. At the Exit 1 interchange, I-93 drops to three northbound lanes. Just after the Exit 1 two-lane off ramp, I-93 drops an additional lane and maintains two northbound travel lanes from Exit 1 through Exit 3 and beyond. The posted speed limit along I-93 is 65 miles per hour (mph) north of Exit 1 and 55 mph south of Exit 1.

I-93 Shoulder Lane Use Considerations/Analysis

The next step in this evaluation was to review the possibility of accommodating use of the shoulder lane under the existing geometry of northbound I-93 between Exit 1 and Exit 3 during the evening peak periods. The traffic demands and levels of service have previously demonstrated the need for added capacity; however, the roadway must be able to physically accommodate the use of the shoulder in a safe manner.

Minimum Recommended Roadway Cross-Section

The implementation of an alternative cross-section for I-93 north utilizing the shoulder as a travel lane requires consideration of the roadway cross-section and other physical obstructions along the roadway.

Currently, I-93 northbound between Exit 1 and Exit 3 provides a typical cross-section of 38 feet, generally consisting of two 12-foot travel lanes, a 4-foot inside shoulder, and a 10-foot outside shoulder. This cross-section meets the minimum recommended American Association of State Highway Transportation Officials (AASHTO) roadway cross-section for a four-lane freeway.

AASHTO does not specifically address design standards for the conversion of the shoulder to peak period use.[3] Applying the minimum AASHTO design criteria for lane width would suggest an overall width of 40 feet to accommodate a third lane of travel (three 12-foot travel lanes, and a 4-foot inside shoulder). AASHTO also recommends that a minimum clear zone of 2 feet from the edge of the travel-way to obstacles such as bridge abutments or guardrail be maintained, and that a desirable clear zone of 30-feet be maintained wherever possible[4]. [It should also be noted that AASHTO recommends increasing the minimum median shoulder width from 4 feet to 10 feet when going from a four-lane (2-lanes in each direction) to a six-lane (3-lanes in each direction) freeway, and preferably 12 feet where trucks exceed 250 vehicles during the design hour[5]. This would suggest that a 46-foot cross-section northbound be provided].

Since AASHTO standards do not specifically address the use of a shoulder lane as a means of providing additional capacity, the use of the shoulder along I-93 in Massachusetts was referred to as a similar design. The I-93 segment in Massachusetts, provides a minimum of 12-feet for the shoulder lane. Where structures or barriers are present, the outside clearance between the edge of travel in the shoulder lane and the structure is a minimum of 2-feet. MassHighway was able to implement this treatment as a temporary measure without impacting any bridge structures. A similar design approach would effectively increase the overall cross-section for the section of I-93 in New Hampshire to 42-feet.

Implications for I-93

Accommodating the use of the shoulder along I-93 northbound between Exits 1 and 3 for peak period travel would require widening the entire 3.9-mile NB segment to provide a minimum 12-foot shoulder. Furthermore, additional widening in specific locations would be necessary to provide sufficient clear distance from obstacles along the edge of the roadway and to provide for emergency vehicle pulloffs.

In addition to the mainline treatment there are several locations where I-93 travels over or under a bridge structure. These locations can be more problematic because bridge structure modifications are typically more costly than standard roadway modifications.

Again, to provide for a 4-foot median shoulder, two 12-foot travel lanes, a 12-foot shoulder lane, and a minimum 2-foot offset to a bridge abutment or guardrail, a minimum 42-foot cross-section is needed. Based on a review of the corridor, there are a total of seven bridge structures within the study area from and including Exit 1 (Rockingham Boulevard) to Exit 3. These structures were evaluated to determine if adequate clearance exists for the use of the shoulder as a travel lane. The seven bridges along I-93 (running south to north from Exit 1) which were reviewed are:

- **Rockingham Boulevard (Exit 1).** These bridges (2) carry the SB on and off-ramps over I-93. The distance between pier faces is 59 feet. The typical pavement section for I-93 is approximately 49-feet and consists of an 11-foot inside shoulder with an additional 2-foot paved offset from face of existing guardrail to edge of inside shoulder, two 12-foot travel lanes and a 10-foot outside

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[3] The only reference to shoulder travel found in AASHTO is a section discussing the use of the shoulder for slow-moving vehicles (for brief 1000- foot to 3 mile sections) to allow other vehicles approaching from the rear to pass the slow moving vehicle with little or no reduction in travel speed. In this case, AASHTO recommends that the shoulder provide a 12-foot lane to perform this maneuver. While this does not specifically address the actual design relating to the actual use of the shoulder as a general travel-lane, it provides some insight about the possible design of the lane.

[4] AASHTO, *Roadside Design Guide*; Washington D.C.;AASHTO, 1988
[5] Truck volumes are estimated to comprise approximately 240 vehicles of the total northbound design hourly flow on I-93 in the future.

shoulder with an additional 2-foot offset from edge of outside shoulder to face of concrete barrier.

- **NH 38 (Between Exit 1 and Exit 2).** This bridge carries I-93 NB over NH 38. This bridge provides a cross-section of 38 feet. Presently this bridge provides a 4-foot inside offset, two 12-foot travel lanes and a 10-foot outside shoulder.

- **Porcupine Brook (Between Exit 1 and Exit 2).** This bridge carries I-93 over Porcupine Brook. This bridge (box culvert) provides a 38-foot cross-section. This cross-section consists of a 4-foot inside offset, two 12-foot travel lanes and a 10-foot outside shoulder.

- **Pelham Road / NH 97 (Exit 2).** This bridge carries I-93 NB over Pelham Road. This bridge currently provides a 38-foot cross-section. Presently, this bridge provides a 4-foot inside offset, a 12-foot travel lane, a 12-foot travel lane and a 10-foot outside shoulder.

- **Brookdale Road (Between Exit 2 and Exit 3).** This bridge carries Brookdale Road over I-93. The typical pavement section for I-93 is 38 feet and consists of a 4-foot inside shoulder, two 12-foot travel lanes and a 10-foot shoulder. A paved apron under the bridge begins 6-feet beyond the edge of the 10-foot shoulder and extends up at a 2:1 slope approximately 15 feet to the easterly abutment. The distance from the inner travel way to the face of the center bridge pier is approximately 43.5 feet.

- **NH 111A (Just south of Exit 3).** This bridge carries I-93 NB over NH 111-A. This bridge provides a 37-foot 2-inch cross-section comprised of two 12-foot travel lanes, a 3-foot 7-inch inside shoulder, and a 9-foot 7-inch outside shoulder.

Other Issues to Consider

Exclusive of the traffic volumes and cross-section requirements, there are various design and permitting issues which will need to be addressed if the shoulder is to be opened to general traffic use. The presence of wetlands, grades along the corridor, the design of the merge and diverge areas, and the placement of guardrails and clear zones along the corridor must be considered if the shoulder lane is to be used as a means of increasing capacity along I-93.

With respect to clear zones, based on current AASHTO guidelines, all objects along the edge of the roadway would need to be relocated to provide a minimum of six feet of clearance from the edge of the pavement. Objects that are not moveable must be set on breakaway mountings or protected by attenuators or barriers. At the underpass bridge locations, the roadway will have to be widened on the outside by approximately one to four feet to accommodate the 12-foot shoulder lane and 2-foot offset from any guardrail or other devices separating the bridge abutments from the highway traffic. All guardrail locations will need to be set a minimum of two-feet off the edge of travel way along the entire corridor.

Another issue to consider is the need to provide for emergency pull off locations during the periods when shoulders lanes are in use. By using the shoulder as part of a shoulder lane measure to increase capacity, the ability for vehicles to exit the travel way under emergency conditions is limited. As a minimum, a clear zone adjacent to the roadway should be provided which would permit the vehicle to exit the travel way (in this case the shoulder). Any location where emergency pullouts cannot be provided should not be considered for shoulder lane use. Previous experience with FHWA has determined that emergency pulloffs should be provided every 2,500 feet, if possible, with advanced informational signage provided every 1,000 feet and 500 feet prior to the pulloff location.

Findings

Review of the existing conditions along I-93 north from the Massachusetts/New Hampshire border to Exit 3 concluded the following:

- Safety statistics associated with other locations where the shoulder is used as a means of increasing capacity indicate that there is a general statistical increase in traffic accidents associated with the usage of the lanes. However, as drivers become more familiar with the use of the lanes, accident rates decline over time (although accident rates remain higher than pre-usage periods).

- As noted in the I-93 *Scoping Report*, the existing traffic volumes and operations indicate that I-93 within the study area is currently over capacity. This congestion suggests that the corridor could benefit from peak period use of a shoulder lane as a temporary traffic management solution. However, as described below, given existing physical constraints along the corridor, this is not a quick or low-cost alternative.

- Based on the recommended minimum cross-sections, there is inadequate width to accommodate the proposed use of the shoulder over the 3.9 miles between Exits 1 and 3, without widening the entire roadway corridor by an average of two to four feet.

  Much of the widening for the shoulder lane between Exits 1 and 2 would also require additional widening beyond the shoulder lane pavement to accommodate guardrail due to the steep fill slopes. This widening would result in impacts to wetlands, including prime wetlands, adjacent to I-93. The section of I-93 between the Pelham Road bridge and the Brookdale Road bridge (approximately 3000 feet) will require additional widening due to the narrowness as the Exit 2 NB on-ramp merges with the mainline. The NB on-ramp at Exit 2 would also require reconstruction to accommodate the additional width for the shoulder lane.

- Based on the AASHTO recommended minimum pavement cross-section, the I-93 NB bridges over Porcupine Brook, NH 38, Pelham Road, and NH 111-A between Exit 1 and Exit 3 would require widening of approximately four feet to accommodate the 42-foot of width criteria.

  At the Brookdale Road bridge over I-93 NB, the existing 10 foot shoulder under the bridge would require widening, two feet and include modifications to the stone paving to accommodate the installation of guardrail or barrier protection to allow for a two foot offset to the shoulder lane.

  The two Rockingham Boulevard bridges over I-93 NB currently provide approximately 49-feet of width between the guardrail on the east and the concrete barrier on the west or outside of the NB barrel. To accommodate a shoulder lane the existing 11-foot inside shoulder would need to be widened one foot and the existing guardrail replaced with a concrete barrier offset at two feet from the inside shoulder.

- Additional clearance to fixed objects on the side of the roadway will also need to be provided. Guardrails and barriers must have a 2-foot minimum clearance from the edge of pavement, while signs require 6-feet of clearance.

- The close proximity of the interchange spacing between Exits 1 and 2 would reduce the effectiveness of shoulder lane operating conditions and increase safety concerns associated with traffic exiting and entering I-93 in this area.

- The existing horizontal and vertical geometry in the section of I-93 between Exits 2 and 3 is not desirable for shoulder lane use. The 4-5 percent grades in combination with near maximum roadway design curvatures further compromise safety relative to shoulder lane use.

- The implementation of shoulder lanes north of Exit 3 and along the SB barrel of I-93 between Exits 1 and Exit 5, although not fully evaluated, would face similar difficulties as discussed in the preceding text. The need to widen bridges, improve clear zone offsets, and provide for emergency pulloffs would be similarly problematic.

Recommendations

The existing cross-section along the entire 3.9-mile section of the I-93 northbound barrel will require some amount of geometric improvements prior to utilizing the shoulder as a means of providing additional capacity. The construction activities and improvements associated with the widening of the corridor and the widening and/or modification of seven bridges would require a substantial capital investment and environmental coordination and permitting. While utilizing the shoulder lane as a means of increasing the capacity of the corridor would help in the near-term, it should be viewed as a temporary solution only. The construction activities, including traffic control, necessary to complete the construction of the shoulder lane would further disrupt the existing traffic flow and further increase congestion for, in all likelihood, a two-year construction period. The actual use of the shoulder lane, once completed, may have only a one or two year life with the more permanent solution being contemplated to begin construction in 2004. The capital investment needed to meet the current AASHTO standards for shoulder lane use would be better spent on a more permanent transportation solution, with the completion of the section of I-93 between Exits 1 and 2 given a priority.

For these reasons, it is recommended that the use of the shoulder as a means of increasing capacity along I-93 northbound between Exit 1 and Exit 3 be discontinued from further consideration and that other, more permanent options be considered in its place.